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(54) **A mechanical sensor**

Ein mechanischer Sensor

Une sonde mécanique

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- **JAPANESE PATENTS ABSTRACTS (UNEXAMINED) Week 8933, Derwent Publications Ltd., London, GB; AN 89-238287 & JP-A-1 173 702 (MATSUSHITA ELEC IND KK) 10 July 1989**
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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates to a mechanical sensor, and more particularly to a mechanical sensor capable of detecting with high sensitivity, stress or strains.

2. Description of the Related Art:

In recent years, under the circumstances that electronic equipment is made smaller and thinner, there is a great demand for further miniaturization of mechanical sensors used in electronic equipment. A mechanical sensor utilizing a stress-magnetic effect has been put into practical use (e.g., see SAE Technical Paper Series 920700). Such a mechanical sensor is formed of a cylinder, to which an amorphous magnetic ribbon having a positive magnetostriction constant adheres, and detects the change of the permeability of the amorphous magnetic ribbon due to the stress applied thereto, by using a solenoidal coil.

The above-mentioned conventional mechanical sensor has a coil made of a conductive line with a diameter of about 20 to 30 μm, wound in a solenoidal shape and a magnetic bulk having a thickness of about 20 to 30 μm.

The above-mentioned conventional mechanical sensor has the following problems: Since such a mechanical sensor has a solenoidal coil and a magnetic bulk, it is difficult to miniaturize and integrate the sensor. In addition, since the thickness of the magnetic layer is in the range of 20 to 30 pm, and the diameter of the conductive line is in the range of 20 to 30 μm, there is a limit to the frequency of the sensor.

An example of a planar mechanical sensor suitable for the miniaturization is a strain gauge using a metallic foil. The sensitivity of the strain gauge is one-thousandth or less of that of the mechanical sensor utilizing a stress-magnetic effect.

DE 41 17 878 Al discloses a planar magnetic element comprising a substrate and a first magnetic layer disposed thereon, an insulating laser disposed above the first magnetic layer, a planar coil consisting of a single conductor having a plurality of windings, which is disposed above the first insulating layer, a second insulating layer disposed above the planar coil, and a second magnetic layer disposed above the second insulating layer. This device can be used as an inductance device or a transformer.

EP 0 329 479 A2 discloses a strain gage including a pair of coils printed on one face of a substrate and an amorphous magnetic metallic plate arranged on the other face of said substrate, having a magnetostrictive effect. Magnetic flux is geneated by one of the paired coils and passes through the amorphous magnetic metallic plate and links with the other of the coils. If a load is added to an object to be measured and strain of the object is caused by the load added, the magnetic permeability of th e amorphous magnetic metallic plate is changed, due to the magnetostrictive effect, in response to the added load. The density of the magnetic flux passing through the magnetic metallic plate is also changed responsive to this changing magnetic permeability and composite inductance of the paired coils is then changed responsive to the changing density of the magnetic flux. The strain gage outputs a detection signal, which represents the changing density of the magnetic flux, thereby measuring the load added.

SUMMARY OF THE INVENTION

The mechanical sensor of this invention, includes:

a magnetic layer having permeability which is changed in accordance with stress generated therein;
a coil having at least two terminals, allowing an electric current to flow therebetween to generate a magnetic flux, thereby magnetizing the magnetic layer; and
a substrate integrally supporting the magnetic layer and the coil,
wherein the coil is a planar coil including at least one winding, each winding having a U-shaped portion formed of a first conductive line portion, a second conductive line portion, and a connecting portion connecting the first and second conductive line portions, the first and second conductive line portions extending in a first direction, the connecting portion extending in a second direction being vertical to the first direction, and impedance between the terminals is changed in accordance with a change of inductance caused by a change of the permeability of the magnetic layer,
wherein the total length of each linear conductive line portion extending in the first direction is larger than the total length of each linear conductive line portion extending in the second direction; and the magnetic layer is magnetized substantially in a direction orthogonal to the first direction.

In one embodiment of the present invention, the coil is a planar coil including at least two windings, and a distance between conductive line portions in which an electric current flows in the same direction is smaller than a distance between conductive line portions in which an electric current flows in the opposite directions to each other.

In still another embodiment of the present invention, the coil is formed on an insulator layer supported by the substrate.

In still another embodiment of the present invention, the magnetic layer is formed between the insulator layer

and the substrate.

In still another embodiment of the present invention, the magnetic layer is formed on the coil with another insulator layer formed therebetween.

In still another embodiment of the present invention, the magnetic layer has a two-layered structure and sandwiches the coil.

In still another embodiment of the present invention, the mechanical sensor includes further a second U-shaped portion formed of a third conductive line portion, a fourth conductive line portion, and a connecting portion connecting the third and fourth conductive line portions, the first, second, third, and fourth conductive line portions extending in a first direction; and

wherein the first and second U-shaped portions are connected in series between the terminals.

Thus, the invention described herein makes possible the advantage of providing a mechanical sensor with high sensitivity capable of being made small, thin, and integrated.

This and other advantages of the present invention will become apparent to those skilled in the art upon reading and understanding the following detailed description with reference to the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure **1** is a partially perspective plan view showing a mechanical sensor of the present invention.

Figure **2** is a cross-sectional view taken along a line **A-A'** of Figure **1**.

Figure **3** is a cross-sectional view taken along a line **B-B'** of Figure **1**.

Figure **4** is a perspective view showing another mechanical sensor of the present invention.

Figure **5** is a cross-sectional view taken along a line **G-G'** of Figure **4**.

Figure **6** is a partially perspective plan view showing still another mechanical sensor of the present invention.

Figure **7** is a cross-sectional view taken along a line **J-J'** of Figure **6**.

Figure **8** is a cross-sectional view taken along a line **K-K'** of Figure **6**.

Figures **9A** through **9C** show examples of planar coils used in the mechanical sensors of the present invention.

Figures **10A** through **10C** show examples of planer coils used in the mechanical sensors of the present invention.

Figures **11A** and **11B** show examples of planer coils used in the mechanical sensors of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, the present invention will be described by way of illustrative examples with reference to the drawings.

Example 1

Figure **1** is a plan view showing the structure of a mechanical sensor of the present invention. Figure **2** is a cross-sectional view taken along a line **A-A'** of Figure **1**, and Figure **3** is a cross-sectional view taken along a line **B-B'** of Figure **1**.

Hereinafter, the structure of the mechanical sensor of the present example will be described with reference to these figures.

Referring to Figure **2**, the cross-sectional structure of the mechanical sensor will be described. A magnetic layer **12a** having a thickness of 5 μm is formed on a substrate **11** made of phosphor bronze, having a thickness of 0.5 mm. The substrate **11** can be made of any non-magnetic substance. The substrate **11** can be cylindrical, instead of being in a planar shape as shown in Figure **2**. The magnetic layer **12a** is made of an Fe based amorphous film formed by a sputtering method and contains Fe, Cr, Si, and B. The relative permeability and magnetostriction constant of the magnetic layer **12a** at a frequency of 1 MHz are 100 and +22 ppm, respectively.

On the magnetic layer **12a**, an insulator layer **13a** made of SiO_2, having a thickness of 2 μm is formed. On the insulator layer **13a**, a planar coil **14** made of an aluminum film having a thickness of 5 μm and input/output terminals **15a** and **15b** (not shown in Figure **2**) are formed.

The input/output terminals **15a** and **15b** are applied with a predetermined AC voltage, whereby an electric current flows through the planar coil **14**. In the present specification, any each portion of the conductive line is called a line segment. The line segment is not limited to a linear shape, unless otherwise stated. In the planar coil **14**, the minimum distance between conductive line portions (i.e., line segments), which are adjacent to each other and in which an electric current flows in the same direction, is 10 μm. More specifically, each distance between conductive line portions **14a** and **14b**, between conductive line portions **14c** and **14d**, between conductive line portions **14e** and **14f**, and between conductive line portions **14g** and **14h** is 10 μm. The minimum distance between the conductive line portions in which an electric current flows in the opposite directions to each other is 180 μm (see Figure **1**). More specifically, each distance between the conductive line portions **14b** and **14c**, between the conductive line portions **14d** and **14e**, and between the conductive line portions **14f** and **14g** is 180 μm. An insulator layer **16** having the same thickness as that of the planar coil **14** fills between the conductive line portions in which an electric current flow in the same direction.

On the insulator layer **13a**, another insulator layer **13b** is formed so as to cover the planar coil **14**. The insulator layer **13b** (thickness: 2 μm) is made of the same material as that of the insulator layer **13a**. The insulator layer **13b** fills gaps between any conductive line portions

in which an electric current flows in the opposite directions to each other. On the insulator layer **13b**, another magnetic layer **12b** is formed. The magnetic layer **12b** (thickness: 5 μm) is made of the same material as that of the magnetic layer **12a**. In this way, in the present example, the planar coil **14** is sandwiched between the magnetic layers **12a** and **12b**.

Referring to Figure **1**, the planar structure of the mechanical sensor will be described. The substrate **11** has a rectangular shape with a longitudinal side of 30 mm and a vertical side of 15 mm. The planar coil **14** is formed in a rectangular region on the substrate **11**, the rectangular region having a length **C** of 3000 μm in a first direction **F** and having a width **D** of 820 μm in a second direction **E** which is vertical to the first direction **F**. As shown in Figure **1**, the planar coil **14** of the present example has a basic structure including two windings on a plane (i.e., a double spinal structure). More specifically, the planar coil **14** has a basic structure in which each of the two windings of the planar coil **14** has first and second U-shaped portions connected in series. Each of the first U-shaped portions has first and second linear conductive line portions extending along the first direction **F** and a connecting portion connecting the first and second linear conductive lines. Likewise, each of the second U-shaped portions has third and fourth linear conductive line portions extending along the first direction **F** and a connecting portion connecting the third and fourth linear conductive line portions. Alternatively, it is considered that each of the second and third linear conductive line portions and the connecting portions connecting each of the second and third linear conductive line portions form other U-shaped portions extending in the direction opposite to those of the first and second U-shaped portions.

Because of the above-mentioned structure, a planar coil can be obtained in which the total length of each linear conductive line portion extending in the first direction **F** is sufficiently larger than the total length of each linear conductive line portions extending in the second direction **E**. In addition, in a predetermined area, the total length of each linear conductive line portion extending in the first direction **F** is larger than that of the other structure. The number of windings can be one, or three or more, instead of two.

The shape of the planar coil **14** can be the same as those shown in Figures **9A-9C**, **10A-10C**, **11A** and **11B**. For simplicity, these figures show planar coils including one winding on a plane. However, as shown in Figure **1**, if wire bonding is used, a planar coil including two or more windings can be obtained. In addition, the number of U-shaped portions of each winding is not limited to those shown in these figures.

The magnetic layer **12b** covers the main portion of the planar coil **14**, as shown in Figure **1**. The planar coil **14** is provided with a projected portion **17** which is not covered with the magnetic layer **12b**. Over the projected portion **17**, an internal end **18** of the planar coil **14** is connected to the input/output terminal **15a** with a gold wire **19** by wire bonding. Because of this, the planar coil **14** including two windings can be produced by a single photolithography process.

The planar coil **14** with the above-mentioned structure has the following two advantages.

Firstly, the magnetic layers **12a** and **12b** two-dimensionally formed can be effectively used as much as possible as a magnetic core of the planar coil **14**. The following is generally known: Assuming that a certain distance (i.e., characteristic length) at which the magnetic flux of the magnetic layers 12a and **12b** is attenuated to 1/e is λ, then $\lambda = (\mu r \cdot g \cdot tm/2)$(see, IEEE Tr. Magn. MAG14, pp. 509-511). Here, μr represents relative permeability of the magnetic layers **12a** and **12b**; g represents a gap thereof; and tm represents a layer thickness thereof. If the above-mentioned values are substituted in this equation, λ = 32 μm. That is to say, the magnetic flux is attenuated to 1/e at a distance of 30 μm from each conductive line portion. This characteristic length λ is relatively small. The reason for this is that the magnetic layers **12a** and **12b** have a relatively small thickness (i.e., 5 μm) and have small relative permeability (i.e., 100). Since the characteristic length λ is small, even though the planar coil **14** is formed in a certain limited area as shown in Figure **1** (in which parts of the planar coil **14** are bent), the bent portions have little effect on the magnetic flux formed by the other portions of the planar coil **14**. Thus, the magnetic layers **12a** and **12b** can be effectively used as much as possible as a magnetic core. It is preferred that the distance between the two adjacent conductive line portions in which an electric current flows in the opposite directions to each other is sufficiently larger than the characteristic length λ. The reason why the distance between the adjacent conductive line portions in which an electric current flows in the same direction is made as small as possible is to minimize the magnetic flux leaking between the conductive line portions. Since the distance between the conductive line portions in which an electric current flows in the same direction is 10 μm in this case, this value is sufficiently smaller than the characteristic length λ and thus, less magnetic flux is leaked. Because of this, the inductance of the planar coil **14** is increased in proportion to nearly the square of the number of windings.

Secondly, in a case where the planar coil **14** is formed as shown in Figure 1, the planar coil **14** can magnetize the magnetic layers **12a** and **12b** substantially in one direction as a whole. When stress is applied to the magnetic layers **12a** and **12b** having magnetostriction, magnetic anisotropy is induced in the stress direction due to magnetoelastic energy; as a result, the permeability in the stress direction is changed. Since the mechanical sensor of the present example detects the change of the permeability as the change of inductance, it is required that the magnetizing direction and the stress direction are aligned as much as possible. In a case where the conductive line and the magnetic layers

12a and **12b** are formed on the substrate, the flat conductive line and the magnetic layers **12a** and **12b** are in parallel with each other. Because of this, the magnetizing direction is in parallel with the inner surface of the magnetic layers **12a** and **12b** and is orthogonal to the conductive line. In addition, since the stress generated in the magnetic layers **12a** and **12b** has the same magnitude as that generated on the surface of the substrate **11**, it is considered that in the magnetic layers **12a** and **12b**, stress which is in parallel with the surface of the magnetic layers **12a** and **12b** is generated. Because of this, the planar coil **14** shown in Figure **1** can selectively detect only the stress which is in substantially parallel with the direction **E**.

Hereinafter, the operation of the mechanical sensor of the present example will be described.

When the substrate **11** is pressurized, stress and strain having components in parallel with the direction **E** are generated on the surface of the substrate **11** (namely, the magnetic layers **12a** and **12b**). Assuming that the angle formed by each line segment of the planar coil **14** and the second direction **E** is represented by θ, and the change of inductance of the planar coil **14** caused by the stress is represented by ΔL. ΔL is in proportion to a component of the magnetizing direction of stress generated on the surface of the substrate **11**. Because of this, ΔL is represented by the following Equation (1):

$$\Delta L = k_1 \times \delta \times (R\sin\theta + S\cos\theta) \qquad (1)$$

where k_1 is a proportional constant, δ is stress, R is total length of the line segments of the planar coil **14** sandwiched between the magnetic layers **12a** and **12b** in the direction **F**, and S is total length of the line segments of the planar coil **14** thereof in the direction **E**.

It is understood from Equation (1) that ΔL becomes maximum in a case where R/S is large and θ is close to 90°. Thus, the planar coil **14** is placed so that R/S is large and e is close to 90°. When R/S is large, cross talk (output component caused by the stress in the direction shifted by 90° from the direction of stress generated on the surface of the substrate 11) can be minimized.

The above-mentioned conditions can be satisfied in the structure of the present example. That is, as shown in Figure **1**, the planar coil **14** is bent in a rectangular wave shape and the length of the line segments extending in a certain direction is made larger than that of the other line segments extending in the other direction. In the present example, θ is set at 90°.

The distance between the adjacent conductive line portions in which an electric current flows in the opposite directions to each other is determined, considering the characteristic length λ. In a case where this distance is too large, R/S becomes small, increasing the area which is not magnetized. In contrast, in a case where this distance is too small, the inductance becomes small. In the present example, the distance between the adjacent conductive line portions in which an electric current flows in the opposite directions to each other is set at about 6 times the characteristic length λ. In the present example, R is 23000 μm and S is 1600 μm, so that R/S is 14.4.

The same effects as those obtained by using the planar coil **14** can also be obtained by using a meander coil (e.g., IEEE Tran. Magn. MAG-20, pp. 1804-1806, 1984). The meander coil has the following advantages: A step of connecting the internal end **18** to the input/output terminal **15a** is not required, and the resonance frequency is increased. However, since the number of windings of the meander coil is one, the inductance is relatively low.

In the case of another planar coil for zero correction, since ΔL becomes minimum at θ = 0, the planar coil is placed on the substrate **11** so that θ becomes 0. In addition, since the minimum value of ΔL is in proportion to S, it is preferred that R/S is large.

<u>Example 2</u>

Figure **4** is a perspective view showing the structure of another mechanical sensor according to the present invention. Figure **5** is a cross-sectional view taken along a line **G-G'** of Figure **4**.

A substrate **21** has an insulating property at least on the surface thereof. The substrate **21** has a longitudinal side of 30 mm, a vertical side of 15 mm, and a thickness of 0.5 mm. On the substrate **21**, a conductive line **22** made of an aluminum film with a thickness of 4 μm is formed. The conductive line **22** winds around a magnetic layer **24** covered with an insulator layer **23** in a solenoidal shape. Thus, the conductive line **22** forms a solenoidal coil. A thin portion of the insulator layer **23** has a thickness of 2 μm, and a thick portion thereof is 7 μm. As shown in Figure **5**, an insulator layer **25** is formed between the respective portions (which are in contact with the respective portions (which are in contact with the substrate **21**) of the conductive line **22**, the insulator layer **25** having the same thickness as that of the conductive line **22**. The magnetic layer **24** is made of an Fe based amorphous film (thickness: 5 pm) formed by a sputtering method. The magnetic layer **24** has a rectangular shape (2000 pm x 3000 pm). The relative permeability and magnetostriction constant of the magnetic layer **24** at a frequency of 1 MHz are 100 and +22 ppm, respectively.

The portions of the conductive line **22** positioned above and below the magnetic layer **24** extend in the direction orthogonal to the longitudinal direction (hereinafter, this longitudinal direction is referred to as a direction **H**) of the magnetic layer **24**. The reason for this is that the conductive line **22** magnetizes the magnetic layer **24** in the direction **H**. The portions (bent portions) of the conductive line **22** connecting the portions of the

conductive line **22** positioned above the magnetic layer **24** with the portions of the conductive line **22** positioned below the magnetic layer **24** are not in parallel with the direction orthogonal to the direction H, as shown in Figure **4**. Thus, the bent portions magnetize the magnetic layer **24** in the direction shifted from the direction H. However, since the magnetic layer **24** is not present in the vicinity of the bent portions of the conductive line **22**, the magnetic flux generated by the bent portions hardly influences the magnetic layer **24**. In Figure **4**, for making it easy to see the conductive line **22**, the insulator layer **25** is omitted.

Next, the operation of the mechanical sensor of the present example will be described.

Assuming that stress is generated in the longitudinal direction (I direction) of the substrate **21**. In the present example, the conductive line **22** magnetizes the magnetic layer **24** in the direction **H**, so that the change of inductance due to the stress can be represented by the following Equation (2):

$$\Delta L = k_2 \times \delta \cos\theta \qquad (2)$$

where ΔL is the change of inductance, k_2 is a proportional constant, δ is applied stress, and θ is an angle formed by the directions **H** and **I**. As is apparent from Equation (2), when θ is 0°, ΔL becomes maximum; and when θ is 90°, ΔL becomes 0. In the present example, θ is set at 0°, so that ΔL becomes maximum. In addition, from Equation (2), ΔL is almost 0 in a case where θ is shifted by 90° in the present example. Thus, in this case, the cross talk becomes minimum.

In a case where a coil for zero correction is used, it is preferred that θ is set at 90°.

Even though the magnetic layer having magnetostriction extends to the vicinity of the bent portions of the conductive line 22, the mechanical sensor is still effective. In this case, Δ L and cross talk are somewhat increased.

Example 3

Figure **6** is a plan view showing the structure of still another mechanical sensor of the present invention. Figure **7** is a cross-sectional view taken along a line **J-J'** of Figure **6**, and Figure **8** is a cross-sectional view taken along a line **K-K'** of Figure **6**.

A substrate **31** has a longitudinal side of 30 mm, a vertical side of 15 mm, and a thickness of 0.5 mm. On the substrate **31**, magnetic layers **32a** and **32b** made of an Fe based amorphous film having a thickness of 5 μm are formed. The magnetic layers **32a** and **32b** are formed by, for example, a sputtering method. The relative permeability and magnetostriction constant of the magnetic layers **32a** and **32b** at a frequency of 1 MHz are 100 and +22 ppm, respectively. An insulator layer 33a is made of SiO_2 having a thickness of 2 μm, and an insulator layer **33b** is made of SiO_2 having a thickness of 2 to 7 μm. On the insulator layer **33a**, a planar coil **34** made of an aluminum film having a thickness of 5 μm and input/output terminals **35a** and **35b** are formed. The respective shapes of the planar coil **34** and the input/output terminals **35a** and **35b** are the same as those of the planar coil **14** and the input/output terminals **15a** and **15b** as shown in Figure 1. An insulator layer **36** having the same thickness as that of the planar coil **34** fills between the conductive line portions in which an electric current flows in the same direction. An internal end **38** of the planar coil **34** is connected to the input/output terminal **35a** via a gold wire **39**.

For convenience, in Figure **6**, only the planar coil **34** can be seen below the magnetic layer **32b**.

The structure of the mechanical sensor of the present example is basically the same as that of the mechanical sensor as shown in Figure **1**. The difference therebetween is that in the present example, the magnetic layers **32a** and **32b** are formed so that the magnetic layers **32a** and **32b** do not overlap the portions of the planar coil **34** extending in a vertical direction **N** thereof but overlap the portions of the planar coil **34** extending in a longitudinal direction **M** thereof. The size of the magnetic layers **32a** and **32b** is as follows: **P** is 2400 μm and **Q** is 1000 μm.

Next, the operation of the mechanical sensor of the present example will be described.

Assuming that the longitudinal direction of the substrate **31** is in the direction **N**, stress is applied in the direction N, an angle formed by the directions **M** and **N** is θ, and the change of inductance is ΔL. If $R = (2400 \times 8)/23000 \fallingdotseq 0.8R$ and $S = 0$ is substituted in Equation (1), ΔL can be represented by Equation (3):

$$\Delta L = k_1 \times \delta \times 0.8 \times R\sin\theta \qquad (3)$$

As is apparent from Equation (3), when θ is 90°, ΔL becomes maximum, and when θ is 0°, ΔL becomes 0. In the present example, θ is set at 90°.

Compared with Example 1, ΔL is smaller by about 20%. However, when θ is shifted by 90°, ΔL becomes 0, so that the cross talk becomes almost 0. In this respect, the mechanical sensor of the present example is more excellent than that of Figure **1**. In a case where a coil for zero correction is formed at $\theta = 0$, the small cross talk has favorable effects.

In addition, the same structure as that of the present example can be realized by using a meander coil.

In Examples 1 to 3, an Fe based amorphous film having a positive magnetostriction constant, formed by a sputtering method is used as a magnetic layer having magnetostriction. However, any materials having magnetostriction can be used for a magnetic layer. For example, even a magnetic layer having negative magne-

tostriction can be used in the structures of the present invention.

Moreover, in Examples 1 to 3, only magnetic layers having magnetostriction are used. However, a magnetic layer having a magnetostriction of almost 0 and high relative permeability can be used as a part of the magnetic circuit.

According to the present invention, a small and thin mechanical sensor is provided. The mechanical sensor of the present invention effectively uses a magnetic layer which is thinner than the bulk, so that the mechanical sensor of the present invention has high sensitivity for detection irrespective of its thinness. Moreover, the mechanical sensor of the present invention can selectively detect the level of stress in a certain direction with high sensitivity, based on the anisotropy of the sensitivity for detection which does not depend upon the shape of the magnetic layer.

Various other modifications will be apparent to and can be readily made by those skilled in the art without departing from the scope of this invention as claimed.

Claims

1. A mechanical sensor comprising:

   - a magnetic layer (12a, 12b; 24; 32a, 32b) having a permeability which is changed in accordance with stress generated therein;
   - a coil (14; 22; 34) having at least two terminals (15a, 15b; 35a, 35b), allowing an electric current to flow therebetween to generate a magnetic flux, thereby magnetizing the magnetic layer (12a, 12b; 24; 32a, 32b);
   - a substrate (11; 21; 31) integrally supporting the magnetic layer (12a, 12b; 24; 32a, 32b) and the coil (14; 22; 34)
   - wherein the coil (14; 22; 34) is a planar coil including at least one winding, each winding having a U-shaped portion formed of a first conductive line portion (14a, 14d) a second conductive line portion (14b, 14c), and a connecting portion connecting the first and second conductive line portions (14a - 14d), the first and second conductive line portions (14a - 14d) extending in a first direction (F; M), the connecting portion extending in a second direction (E; N) being vertical to the first direction (F; M), and impedance between the terminals (15a, 15b; 35a, 35b) is changed in accordance with a change of inductance caused by a change of the permeability of the magnetic layer (12a, 12b; 24; 32a, 32b);

   characterized in that

   the total length of each linear conductive line portion extending in the first direction (F; M) is larger than the total length of each linear conductive line portion extending in the second direction (E; N); and

   the magnetic layer (12a, 12b; 24; 32a, 32b) is magnetized substantially in a direction orthogonal to the first direction (F; M).

2. A mechanical sensor according to claim 1, wherein a distance between conductive line portions in which an electric current flows in the same direction is smaller than a distance between conductive line portions in which an electric current flows in the opposite directions to each other.

3. A mechanical sensor according to claim 1 or 2, wherein the coil (14; 22; 34) is formed on an insulator layer (13a; 23; 33a) supported by the substrate (11;21; 31).

4. A mechanical sensor according to one of the preceding claims, wherein the magnetic layer (12a; 33a) is formed between the insulator layer (13a; 33a) and the substrate (11; 31).

5. A mechanical sensor according to one of the preceding claims, wherein the magnetic layer (12b; 24; 32b) is formed on the coil (14; 22; 34) with another insulator layer (13b; 23; 33b) formed therebetween.

6. A mechanical sensor according to one of the preceding claims, wherein the magnetic layer (12; 32) has a two-layered structure (12a, 12b; 32a, 32b) and sandwiches the coil (14; 34).

7. A mechanical sensor according to one of the preceding claims comprising:

   - a second U-shaped portion formed of a third conductive line portion (14e, 14h), a fourth conductive line portion (14f, 14g), and a connecting portion connecting the third and fourth conductive line portion (14e - 14h) the first, second, third, and fourth conductive line portions (14a - 14h) extending in the first direction (E; M),
   - wherein the first and second U-shaped portions are connected in series between the terminals (15a, 15b).

Patentansprüche

1. Mechanischer Sensor mit:

   einer magnetischen Schicht (12a, 12b; 24; 32a, 32b) mit einer Permeabilität, welche in Abhängigkeit von einer darin erzeugten Belastung bzw. Deformation bzw. Dehnung bzw. Span-

nung verändert wird;
einer Spule (14; 22; 34) mit mindestens zwei Anschlüssen (15a, 15b; 35a, 35b), welche es einem elektrischen Strom ermöglichen dazwischen zu fließen um einen magnetischen Fluß zu erzeugen, wodurch die magnetische Schicht (12a, 12b; 24; 32a, 32b) magnetisiert wird;
einem Substrat (11; 21; 31), welches einteilig bzw. integral die magnetische Schicht (12a, 12b; 24; 32a, 32b) und die Spule (14; 22; 34) stützt bzw. trägt;
wobei die Spule (14; 22; 34) eine planare bzw. ebene bzw. flache Spule ist, welche mindestens eine Wicklung bzw. Windung umfaßt, wobei jede Wicklung einen U-förmigen Abschnitt aufweist, welcher aus einem ersten leitfähigen Leitungsabschnitt (14a, 14d), einem zweiten leitfähigen Leitungsabschnitt (14b, 14c), und einem Verbindungsabschnitt, welcher die ersten und zweiten leitfähigen Leitungsabschnitte (14a - 14d) verbindet, gebildet ist, wobei sich die ersten und zweiten leitfähigen Leitungsabschnitte (14a - 14d) in einer ersten Richtung (F; M) erstrekken, sich der Verbindungsabschnitt in eine zweite Richtung (E; N) erstreckt, welche senkrecht zur ersten Richtung (F; M) ist, und eine Impedanz zwischen den Anschlüssen (15a, 15b; 35a, 35b) in Abhängigkeit von einer Veränderung der Induktivität verändert wird, welche durch eine Veränderung der Permeabilität der magnetischen Schicht (12a, 12b; 24; 32a, 32b) verursacht wird;

dadurch gekennzeichnet, daß

die gesamte Länge eines jeden linearen leitfähigen Leitungsabschnitts, welcher sich in die erste Richtung (F; M) erstreckt, größer ist, als die gesamte Länge eines jeden linearen leitfähigen Leitungsabschnitts, welcher sich in die zweite Richtung (E; N) erstreckt; und
die magnetische Schicht (12a, 12b; 24; 32a, 32b) im wesentlichen in einer Richtung magnetisiert wird, die senkrecht zu der ersten Richtung (F; M) ist.

2. Mechanischer Sensor nach Anspruch 1, wobei der Abstand zwischen den leitfähigen Leitungsabschnitten, in welchen ein elektrischer Strom in die gleiche Richtung fließt, geringer ist als der Abstand zwischen den leitfähigen Leitungsabschnitten, in welchen ein elektrischer Strom in entgegengesetzte Richtungen zueinander fließt.

3. Mechanischer Sensor nach Anspruch 1 oder 2, wobei die Spule (14; 22; 34) aus einer Isolationsschicht (13a; 23; 33a) gebildet wird, welche vom Substrat (11; 21; 31) gestützt bzw. getragen wird.

4. Mechanischer Sensor nach einem der vorhergehenden Ansprüche, wobei die magnetische Schicht (12a; 32a) zwischen der Isolationsschicht (13a; 33a) und dem Substrat (11; 31) ausgebildet ist.

5. Mechanischer Sensor nach einem der vorhergehenden Ansprüche, wobei die magnetische Schicht (12a, 24; 32b) auf der Spule (14; 22; 34) ausgebildet ist mit einer anderen Isolationsschicht (13b; 23; 33b), welche dazwischen ausgebildet ist.

6. Mechanischer Sensor nach einem der vorhergehenden Ansprüche, wobei die magnetische Schicht (12; 32) eine zweischichtige Struktur (12a, 12b; 32a, 32b) aufweist und die Spule (14; 34) zwischen sich aufnimmt.

7. Mechanischer Sensor nach einem der vorhergehenden Ansprüche mit:

einem zweiten U-förmigen Abschnitt, welcher aus einem dritten leitfähigen Leitungsabschnitt (14e, 14h), einem vierten leitfähigen Leitungsabschnitt (14f, 14g), und einem Verbindungsabschnitt gebildet wird, welcher den dritten und vierten leitfähigen Leitungsabschnitt (14e - 14h) verbindet, wobei sich die ersten, zweiten, dritten und vierten leitfähigen Leitungsabschnitte (14a - 14h) in die erste Richtung (E; M) erstrecken,
wobei die ersten und zweiten U-förmigen Abschnitte in Serie zwischen den Anschlüssen (15a, 15b) geschaltet sind.

Revendications

1. Capteur mécanique comportant :

une couche magnétique (12a, 12b; 24; 32a, 32b) comportant une perméabilité qui est modifiée selon la pression générée dessus;
une bobine (14; 22; 34) comportant au moins deux bornes (15a, 15b; 35a, 35b), permettant à un courant électrique de circuler entre elles pour générer un flux magnétique, magnétisant la couche magnétique (12a, 12b; 24; 32a, 32b);
un substrat (11; 21; 31) supportant intégralement la couche magnétique (12a, 12b; 24; 32a, 32b) et la bobine (14; 22; 34);
dans lequel la bobine (14; 22; 34) est une bobine plane comportant au moins un enroulement, chaque enroulement comportant une partie en forme de U formée d'une première partie de ligne conductrice (14a, 14d), une seconde partie de ligne conductrice (14b, 14c), et une partie de connexion connectant les première et seconde parties de ligne conductrice (14a

- 14d), les première et seconde parties de ligne conductrice (14a - 14d) s'étendant dans une première direction (F; M), la partie de connexion s'étendant dans une seconde direction (E; N) verticale à la première direction (F; M), et l'impédance entre les bornes (15a, 15b; 35a, 35b) est modifiée selon un changement de l'inductance causée par un changement de la perméabilité de la couche magnétique (12a, 12b; 24; 32a, 32b);

caractérisé en ce que

la longueur totale de chaque partie de ligne conductrice linéaire s'étendant dans la première direction (F; M) est plus grande que la longueur totale de chaque partie de ligne conductrice linéaire s'étendant dans la seconde direction (E; N); et

la couche magnétique (12a, 12b; 24; 32a, 32b) est aimantée pour l'essentiel dans une direction orthogonale à la première direction (F; M).

2. Capteur mécanique selon la revendication 1, dans lequel une distance entre des parties de ligne conductrice dans lesquelles un courant électrique circule dans la même direction est plus petite qu'une distance entre des parties de lignes conductrices dans lesquelles un courant électrique circule dans les directions opposées les unes aux autres.

3. Capteur mécanique selon la revendication 1 ou 2, dans lequel la bobine (14; 22; 34) est formée sur une couche isolante (13a; 23; 33a) supportée par le substrat (11; 21; 31).

4. Capteur mécanique selon l'une quelconque des revendications précédentes, dans lequel la couche magnétique (12a; 33a) est formée entre la couche isolante (13a; 33a) et le substrat (11; 31).

5. Capteur mécanique selon l'une quelconque des revendications précédentes, dans lequel la couche magnétique (12a; 24; 32b) est formée sur la bobine (14; 22; 34) avec une autre couche isolante (13b; 23; 33b) formée entre les deux.

6. Capteur mécanique selon l'une quelconque des revendications précédentes, dans lequel la couche magnétique (12; 32) comporte une structure à deux couches (12a, 12b; 32a, 32b) et prend en sandwich la bobine (14; 34).

7. Capteur mécanique selon l'une quelconque des revendications précédentes, comportant :

une seconde partie en forme de U formée sur une troisième partie de ligne conductrice (14e, 14h), une quatrième partie de ligne conductrice (14f, 14g), et une partie de connexion connectant la première et la quatrième partie de ligne conductrice (14e - 14h), les première, seconde, troisième et quatrièmes parties de ligne conductrice (14a - 14h) s'étendant dans la première direction (E; M),

dans lequel les première et seconde parties en forme de U sont connectées en série entre les bornes (15a, 15b).

Fig. 1

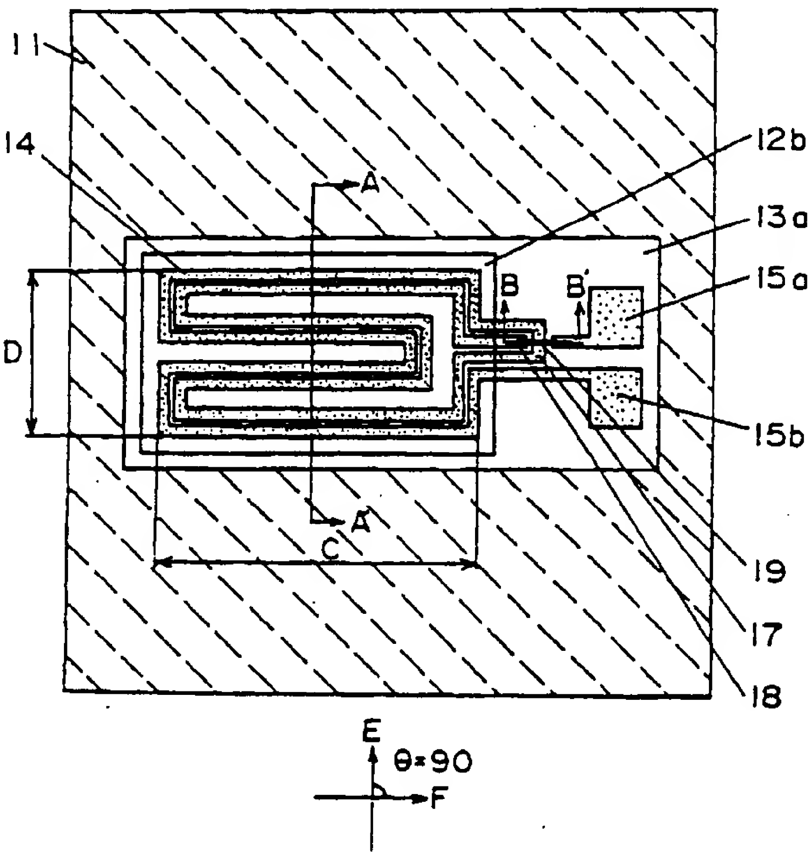

Fig. 2

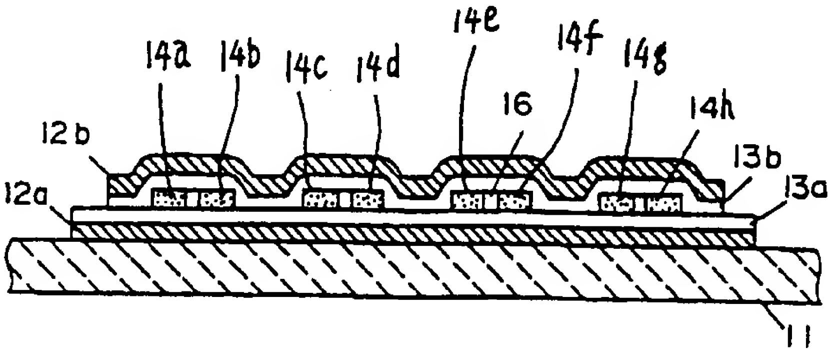
14a
14b
14c
14d
14e
14f
14g
16
14h
12b
13b
12a
13a
11

Fig. 3

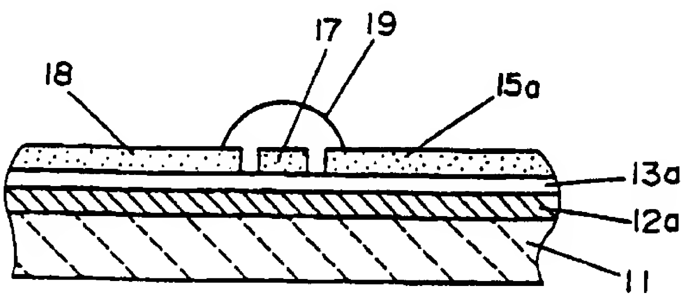
17
19
18
15a
13a
12a
11

Fig. 4

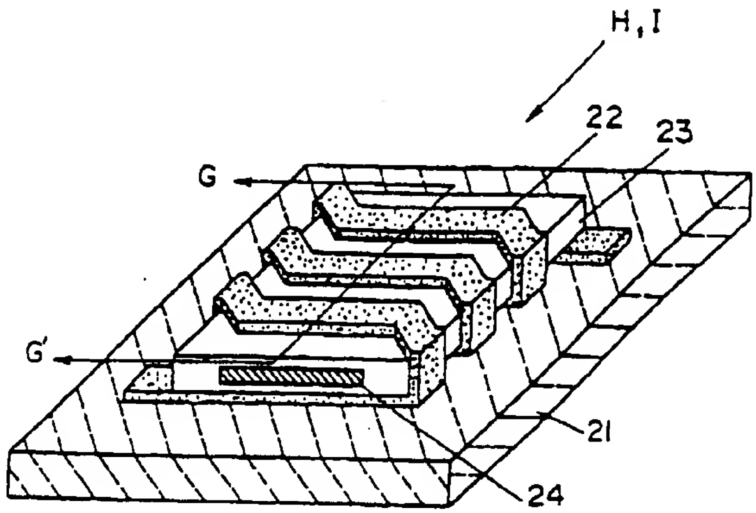

Fig. 5

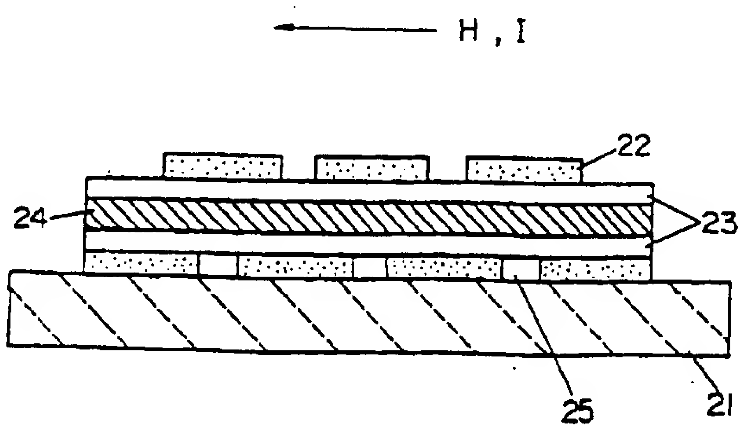

Fig. 6

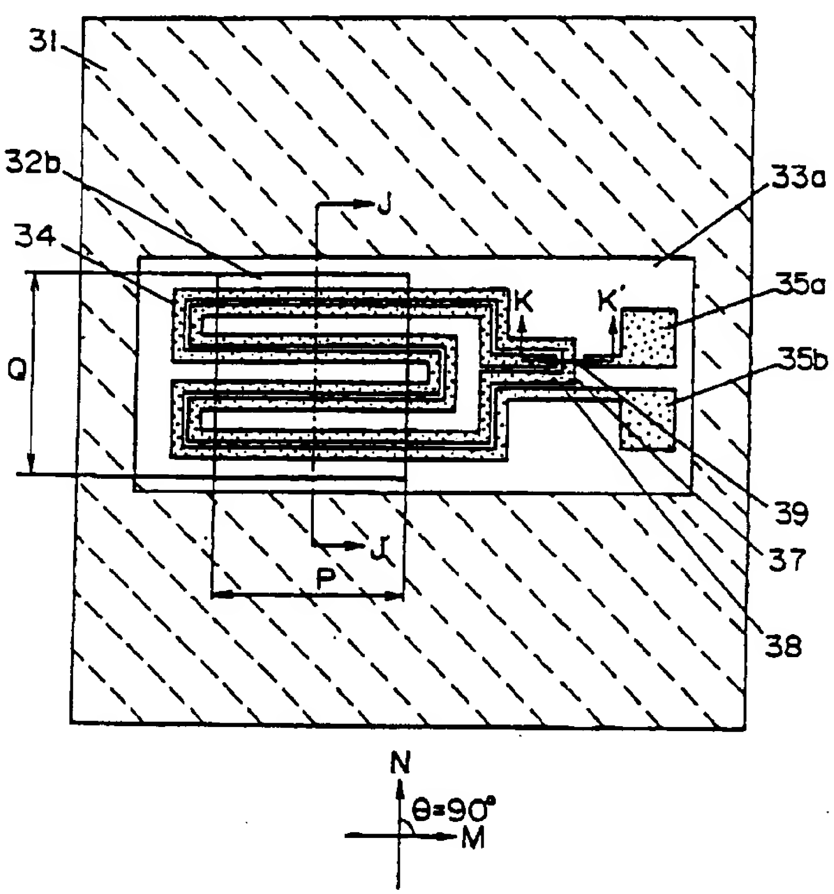

Fig. 7

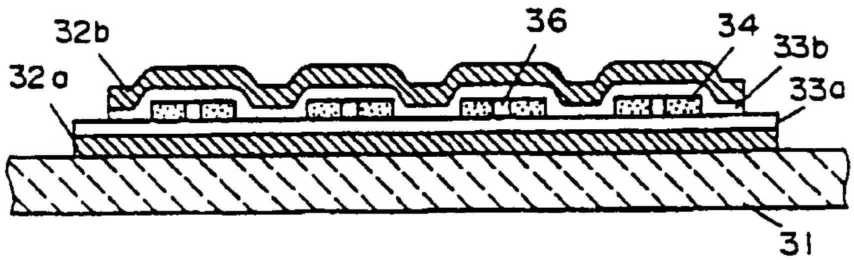

Fig. 8

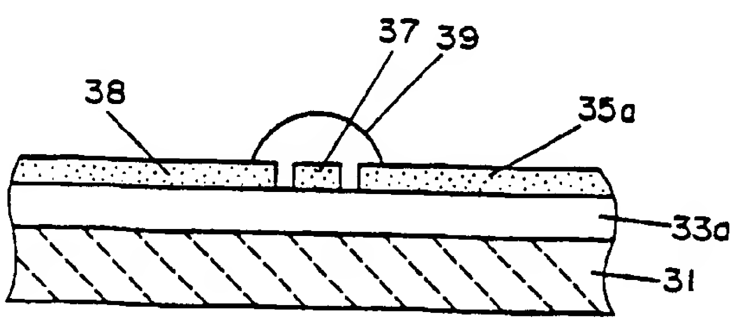

Fig.9A

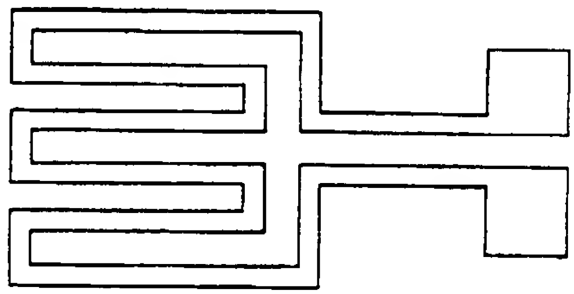

Fig.9B

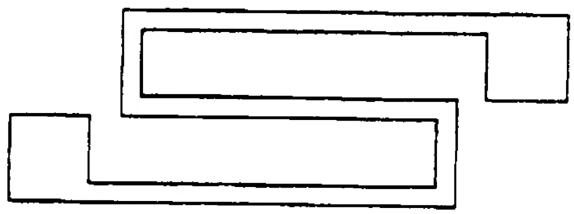

Fig.9C

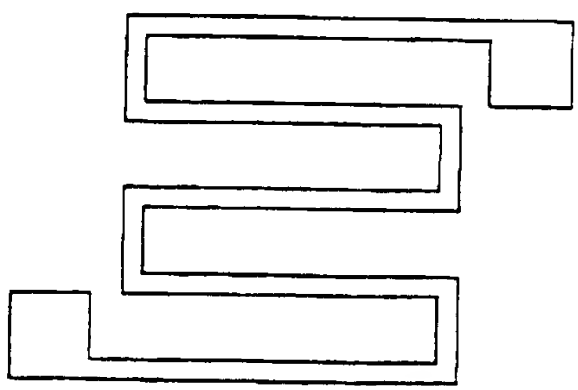

Fig.10A

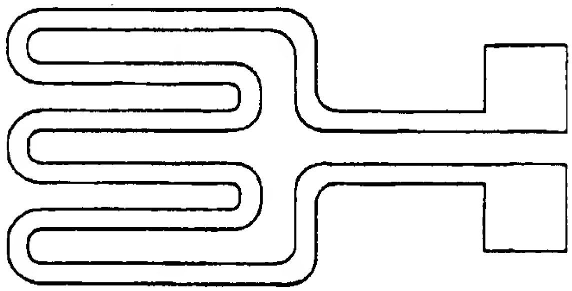

Fig.10B

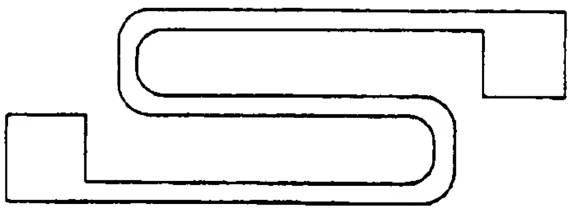

Fig.10C

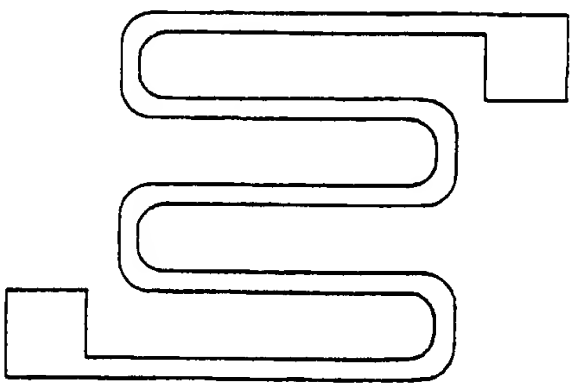

Fig.11A

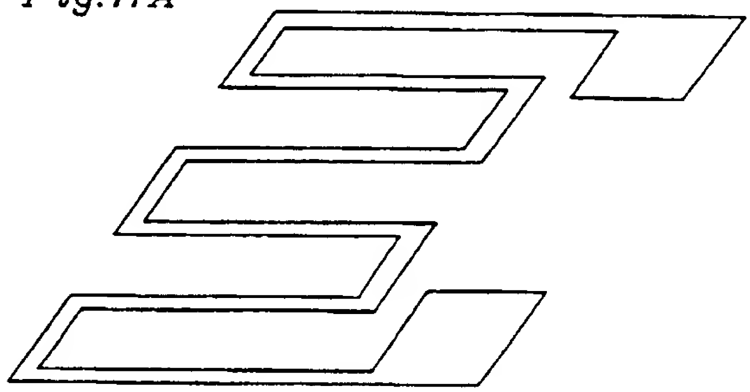

Fig.11B